Urgent restoration in large-scale disaster

- Restoration of pavement in Chuetsu Earthquake -

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ABSTRACT

Roads, representing the social infrastructure, support our daily life and are kept properly by maintenance. However in Japan, where typhoons and earthquakes are experienced frequently, the infrastructure happens to get seriously damaged even though it is well routinely maintained. An earthquake recorded in the central area of Niigata Prefecture on October 23, 2004 caused a disastrous effect in various parts of the region. The Route 17, which was, and is, a principal road in Niigata experienced collapses of the slopes, cracks on the pavement and step-off of the road. The resulting closure of the road made impossible the transportation of goods and the life of the residents along the route was badly affected calling for a prompt remedial action. This paper describes the restoration works on Route 17 as an example of the measures taken immediately after the earthquake and also reports on the full-scale reconstruction works followed later.

1. INTRODUCTION

The social infrastructure, a highway, for example, supports our life, and the maintenance is carried out to keep it in a good condition. However, it sometimes happens that the infrastructure incurs a serious damage, even if the maintenance operation is sufficiently executed, in typhoons and earthquakes to which Japan is prone. The earthquake that occurred in Niigata Prefecture on October 23, 2004 (hereafter referred to as Chuetsu Earthquake) struck a blow in various places there. The National Highway Route 17, a major transportation facility in Niigata, was badly damaged in the form of, among others, collapse of the slopes, cracks on the pavement and step-off of the road. The road was closed to traffic and the transportation of commodities for daily life was made impossible, which caused inconvenience to the daily life of citizens and led to the demand for a prompt response to the disaster. This paper reports on the urgent construction work and the succeeding restoration construction work executed on Route 17.

2. OUTLINE OF CHUETSU EARTHQUAKE

2.1 SCALE OF EARTHQUAKE

The hypocenter of the Chuetsu Earthquake that occurred at 17:56 on Saturday, 23rd of October, 2004, was at about 13km in the underground of Niigata Prefecture (north latitude 37°17’ and east longitude 138°52'), which lies almost in the central part of Japan as shown in Figure1 Its magnitude was 6.8 and the maximum seismic intensity reached up to 7. The maximum acceleration measured

was 2,515 Gal, close to three times the acceleration of 818 Gal that had been observed at the Hanshin-Awaji Earthquake in 1995, which caused the biggest damage in Japan in recent years.

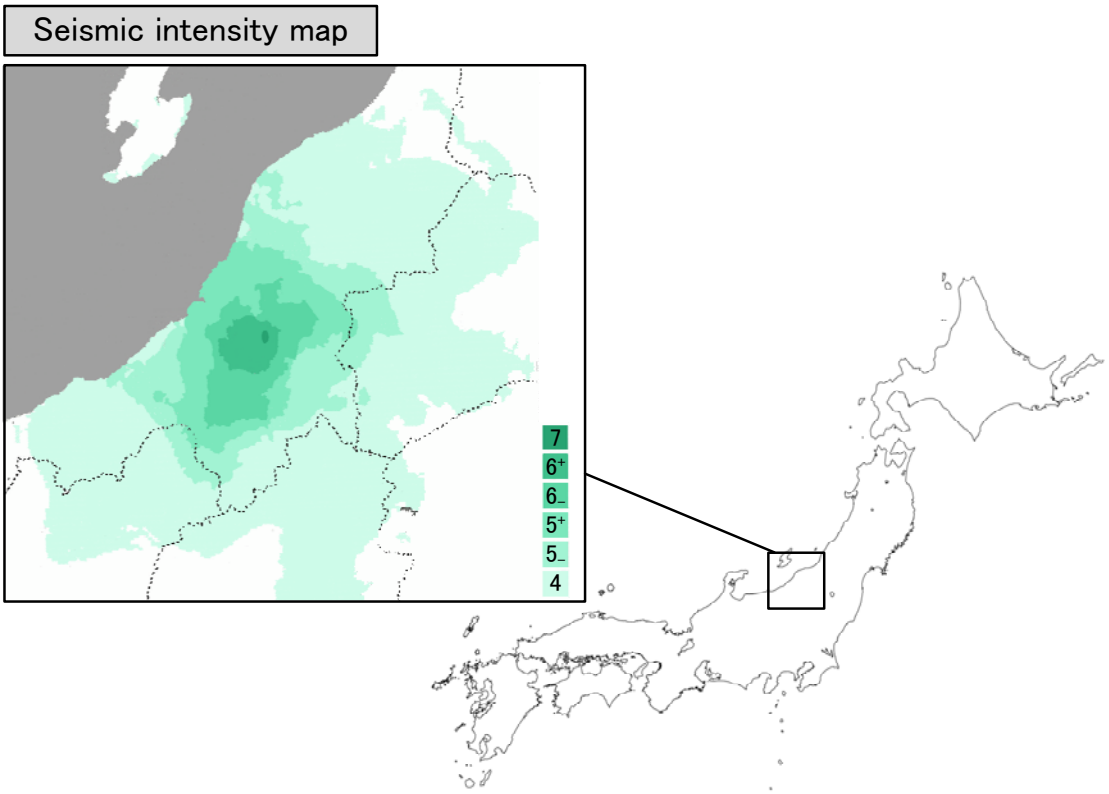

Figure1. Location of earthquake

2.2 DAMAGES CAUSED BY EARTHQUAKE

As shown in Table1, Table2 and Table3, the damages, in terms of human casualties, number of broken houses and amount of lost money, caused by the Chuetsu Earthquake was much smaller when compared with those by the Hanshin-Awaji Earthquake. One of the reasons for the difference was that the region hit by the Chuetsu Earthquake was not so much populated while the area where the Hanshin-Awaji Earthquake occurred was, and is, one of the most densely inhabited areas in Japan. In addition, it was conceivable that there were dominant factors for producing the difference such as the structure of houses in the Chuetsu area with heavy snowfalls built strong enough to endure the weight of snow and the time of earthquake occurring before the snow season.

Table1. Human casualties[1)]

Niigata Chuetsu Earthquake (As of February 1, 2006) (Unit: number of persons)

Month and years of occurrence	Disaster	Human casualties				Total
		Dead	Missing	Serious injury	Light injury	
October-04	Niigata Prefecture Chuetsu Earthquake	59	0	635	4160	4,854
January-95	Hanshin-Awaji Earthquake	6,433	3	10,683	33,109	50,228

Table2. Houses damaged [1)]

Niigata Chuetsu Earthquake (As of February 1, 2006) (Unit: number of houses)

Month and years of occurrence	Disaster	House damaged			Total
		Completely	Partially	Slightly	
October-04	Niigata Prefecture Chuetsu Earthquake	3,175	13,772	103,603	120,550
January-95	Hanshin-Awaji Earthquake	104,906	144,274	263,702	512,882

Table3. Amount of lost money

(Unit: hundred million yen)

	Facilities	Chuetsu Earthquake (%)	Hanshin-Awaji Earthquake (%)
1	Private buildings	11,338 （ 68.5）	58,000 （ 58.4）
2	Railways	625 （ 3.8）	3,439 （ 3.5）
3	Public works facilities including roads	1,934 （ 11.7）	18,525 （ 18.7）
4	Education facilities	172 （ 1.0）	3,352 （ 3.4）
5	Agriculture, forestry and fisheries facilities	1,305 （ 7.9）	1,181 （ 1.2）
6	Health medical treatment and welfare facilities	15 （ 0.1）	1,733 （ 1.7）
7	Utilities for water, electricity, and gas	127 （ 0.8）	4,741 （ 4.8）
8	Communication and broadcasting facilities	32 （ 0.2）	1,202 （ 1.2）
9	Facilities related to commerce and industry	781 （ 4.7）	6,300 （ 6.3）
10	Others	213 （ 1.3）	795 （ 0.8）
Total		16,542（100.0）	99,268（100.0）

2.3 DAMAGES ON ROADS

Damages specifically seen on the roads in the affected area were represented by the following number of completely closed sections after the earthquake; six expressways for a total length of about 580km and a total number of 241 locations of the national highways, of which 17 were maintained by the central government and the rest of 224 by the prefecture. The closed sections and re-opened dates of main highways are shown in Table4 and Figure2.

Table4. Closed sections and re-opened dates of main highways

Highway	Completely closed section	Re-opened date
Kan-etsu Expressway	Nagaoka JCT-Nagaoka IC	Oct-26 22:00
	Koide IC-Gunma Prefecture boundary	Oct-29 12:00
	Nagaoka IC-Koide IC	Nov-05 16:00
Hokuriku Expressway	Kashiwazaki IC-Kakizaki IC	Oct-24 13:50
	Sanjo-tsubame IC –Kakizaki IC	Oct-26 22:00
Route 17	Kawaguchi-cho Wanadu tunnel	Nov-02 16:20

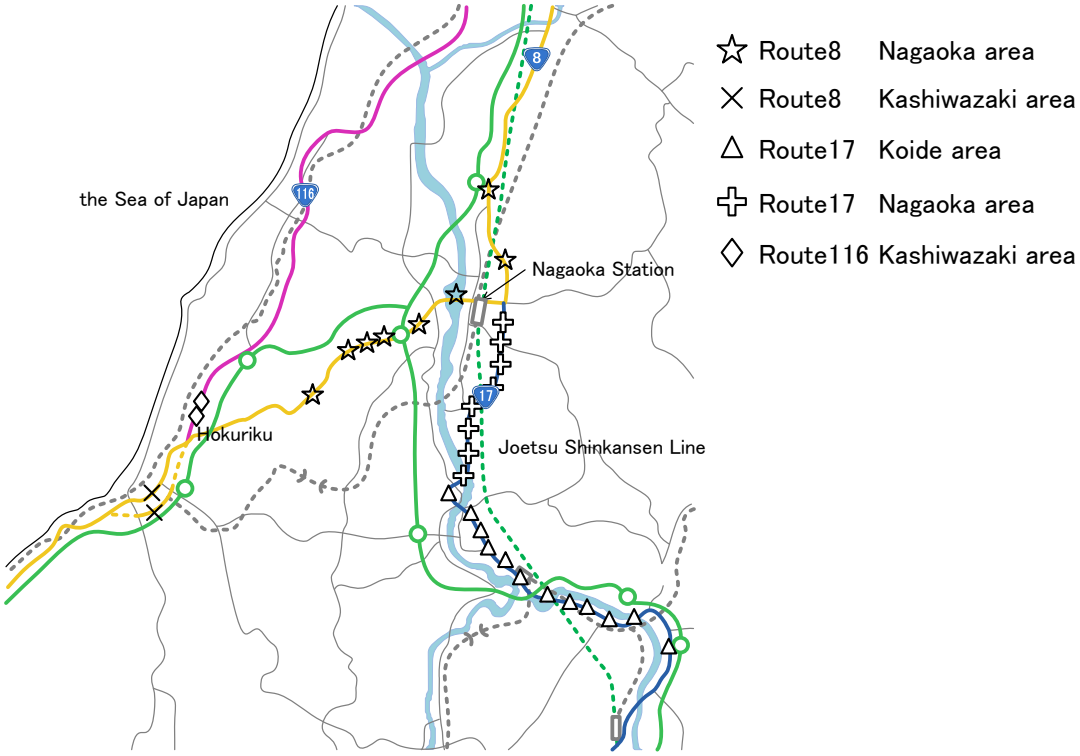

Figure2. Closed sections of main highways

3. CHARACTERISTICS IN DISASTER RESPONSIVE CONSTRUCTION

A two-phase reconstruction was executed; urgent restoration for a length of 14.6km and a full-scale reconstruction for 4.75km as shown in Figure3. There were differences in the construction work between one applied after this type of disaster and the other performed in a normal condition.

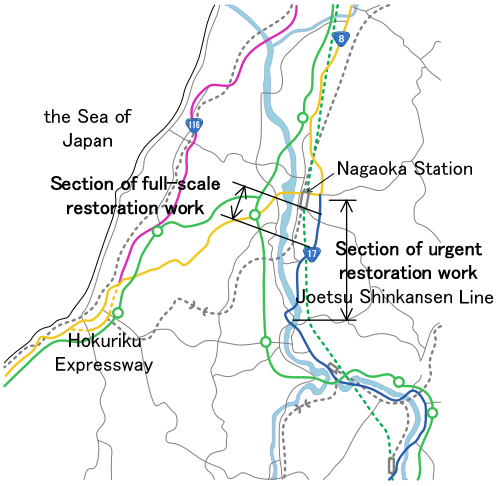

Figure3. Location of construction

(1) TIME FOR CONTRACT AND CONSTRUCTION

The normal procedure in public construction work is that tender information is notified well in advance of bidding and the successful bidder is determined later. Currently in Japan, a comprehensive evaluation system is adopted for public works, in which there are about 40 days between the dates of tender announcement and bidding. In addition, there is time for meetings by the owner and the awarded constructor, and preparation, submission and approval of the construction plan. The time span will be around 120 days. In contrast, only a short period was available, without preparing the construction plan, before the urgent restoration work got started in response to the owner's initiative. The idea was to reopen the road as soon as possible in the order of number of days.

(2) REPAIR METHOD

The share of bituminous pavement in the road pavement in Japan is 95% or more and the design period of its structure is specified to be 10 years based on and in accordance with the accumulated traffic volume on it. Route 17 is a major arterial highway in the Hokuriku region and carries one-way directional traffic of about 15,000 vehicles per day. An example of the pavement structure is shown in Figure4.

Since the use of spiked tire is prohibited in Japan now, most of the pavement distress appears as flow or crack, against which mill-and-overlay method and partial repaving as deep as 40-50mm are commonly applied in the repairing work.

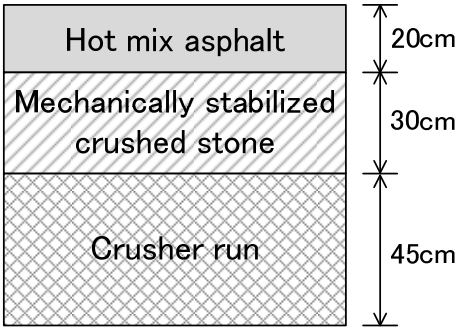

Figure4. Example of pavement structure

4. URGENT RESTORATION CONSTRUCTION

The urgent restoration construction was intended to secure the passage on Route 17 which was cut in numerous sections immediately after the earthquake. The step-offs caused by the earthquake were promptly tapered and restored for the passage. The construction started on the same day when the earthquake occurred and the road was reopened to traffic on its entire section at 9 AM November 1.

4.1 OUTLINE OF CONSTRUCTION

Facts and figures of the project are shown in Table5 and Table6. The construction work mainly aimed at tapering of step-offs, restoring of caved-in sections and repairing of cracked sections. The step-offs were seen at places under which crossing box-type path existed and at the end of bridges.

Table5. Place, period, and owner of construction

Place	Kizu, Ojiya City – Nakazawacho, Nagaoka City (L=14.6km section)
Period	October 23, 2004 – January 31, 2005(7 days for construction work)
Owner	Nagaoka National Highway Office, Hokuriku Regional Development Bureau, The Ministry of Land, Infrastructure, Transport and Tourism.

Table6. Outline of construction

Jurisdiction							
Koide maintenance branch office				Nagaoka maintenance branch office			
Type of works	Average thickness(cm)	Area(㎡)	Number of locations	Type of works	Average thickness(cm)	Area(㎡)	Number of locations
Asphalt pavement	11	435	16	Asphalt pavement	6	3735	58
				Leveling	10	1230	5
				Step-off restoration	5	870	15
				Base-course	15	948	12

4.2 PROBLEMS ENCOUNTERED AND COUNTERMEASURES TAKEN

The construction was executed in an extraordinary situation so that there were problems encountered and measures taken under this circumstance.

(1) SECURING OF MATERIALS AND MACHINE

There are about 1,400 asphalt plants in Japan now, which makes it possible for every one of construction sites in the whole country to be provided with asphalt products almost within an hour of

transportation. In addition, the use of the recycled asphalt mixture and base course materials is required by law, and the reuse of bituminous pavement materials reaches up to 99%. However, it was not possible to ship the materials for the restoration work from the plants in the Niigata district which was badly damaged by the earthquake. And it was considered to be difficult to secure materials and machines. The measures taken were as follows;

- Used mixture was one produced in, and transported from, the Joetsu district and Niigata district away from the construction site. And an additive for warm mix asphalt was used taking into account the time for transportation of about three hours.
- Crushed stone(C-40) was available and used, while recycled crushed stone (RC-40) is used in a normal construction.
- Machine was transported from the Joetsu district and Niigata district.

(2) CLARIFICATION OF TERMS OF REFERENCE

It is common in a normal construction work that numerical values as to the length or area covered by the project, the width and thickness of pavement, etc. are shown in the specification. However, it was necessary to confirm the state of the distress on the site in this construction. Therefore, the construction and repair methods, which were considered fit for the type of damages and applied on the spot, were discussed on and selected by both the owner and constructor beforehand.

- Immediately after the earthquake : Only one lane was restored with the pavement secured in its thickness of 10cm and the step-off was restored by tapering in the stretch of about 5m.
- 2nd and 3rd days : The step-offs on both lanes were restored by about a 5m long tapering.
- 4th through 6th days : The step-off tapering was extended to about 10-20m in consideration of vehicles running at about 20km/h.
- 7th day : Snow was removed. After observing the traffic on the site, the step-off tapering was further extended to secure a running speed of about 40km/h.

4.3 EXAMPLE OF DAMAGED SECTION

A pair of photos below shows a section with a step-off and caving-in before and after the urgent construction work. The passing lane caved in by about 70cm and the part adjacent to a bridge sank by approximately 30cm. Tapering of the step-off in the urgent restoration work was executed with crushed stones and asphalt mixture (t=10cm).

Before **After**

Photo1. Step-off and caving-in before and after urgent construction work

5. FULL SCALE RECONSTRUCTION

The Hokuriku region is one of the areas with heavy snowfall in Japan, and it is difficult to execute construction work in winter. Therefore, a full scale reconstruction was ordered and started in the spring after one winter passed. The reconstruction was aimed at making the urgently restored section back to the state as it had existed before the earthquake. The company for which the authors are working was awarded a 5km section of the restored road in the succeeding year.

5.1 OUTLINE OF CONSTRUCTION

Facts and figures related to the reconstruction are shown in Table7 and Table8. The work included, among others, the following; reconstruction of caved-in section urgently restored on the crossing box-type path, restoration of drainage facilities and guard rails, and stuffing of filling materials in the space under the pavement slab.

Table7. Place, period, and owner of construction

Place	Katatacho, Nagaoka City – Hachibusemachi, Nagaoka City(L=4.75km section)
Period	March 16, 2005 - March 31, 2006(381 days)
Owner	Nagaoka National Highway Office, Hokuriku Regional Development Bureau, The Ministry of Land, Infrastructure, Transport and Tourism.

Table8. Outline of construction

Type of works		Amount
Pavement	Replacement	A=12,217 ㎡
	Overlay	A= 4,348 ㎡
Culvert	Repair work	1 unit
Slope protection	Concrete block work(π type block)	A= 552 ㎡
Drainage structure	Removal, re-installation ,new installation	L= 1,734m
Curb	Removal, re-installation ,new installation	L= 1,630m
Guard rail	Removal, re-installation ,new installation	L= 463m
Incidentals facilities, Blocking of pipes and boxes, Structure removal and Temporary facilities		Lump sum

5.2 PROBLEMS ENCOUNTERED AND COUNTERMEASURES TAKEN

There were again problems encountered in the construction work which was executed in a situation different from normal conditions. The countermeasures taken were as follows;

(1) INCREASE OF QUANTITY IN CONSTRUCTION WORK

Before the work was started, an accurate estimation of the distress on the whole section was not possible, so that confirmations of the section necessary to be repaired were made on the site. This

practice revealed that there were places for reconstruction other than those specified in the contract document. It was found difficult to restore all parts of the damaged road section within the limited period of time, which led to the setting priorities for reconstruction and the completion of construction as much as possible with time and resources available.

(2) SUDDEN RISE OF UNIT PRICE

Seen were rise in unit price of asphalt and increase in hauling cost due to material shortage, therefore construction management was carefully performed in details to keep the loss in time and materials used for the work as minimum.

(3) TIME AVAILABLE FOR DISPOSAL OF INDUSTRIAL WASTE

Industrial waste processing at existing disposal facilities in the Nagaoka district reached their capacity, therefore the recruitment from distant places like the Niigata district and the Joetsu district was made possible with the assistance by companies in close business contact.

(4) SECURING OF PERSONNEL FOR CONSTRUCTION WORK AND TRAFFIC CONTROL

It was impossible to secure labor force for the construction in the Nagaoka district. The recruitment from distant places like the Niigata district and the Joetsu district was made possible with the assistance by companies in close business contact.

(5) REGULATION OF TRAFFIC

The restoration construction works were in a rapid progress in various places in the Nagaoka district, resulting in the lack of working force and equipment for traffic control. This situation forced the procurement from adjoining district far from the construction site.

In addition, the reconstruction work was executed with the part of the lanes closed day and night while paving construction in an urban area in a normal condition is implemented at night for reducing congestion due to the work and the transportation of construction materials and disposing of waste are conducted in daytime. And also, while the length of controlled section is designed to be as short as possible in a normal situation, it was determined in the reconstruction to be the section between one intersection and the neighboring intersection (approximately 300-800m) in order to prevent accidents while merging from occurring.

(6) UNIFICATION OF REMEDIAL MEASURES

Since the utmost purpose of the reconstruction was to reopen the damaged section to be rebuilt as it had been, it was not possible to conduct a detailed investigation into the pavement structure, bearing capacity of the sub-grade, drainage system and so on before the construction work got started. So that the area and section for reconstruction were determined on the site and the work was performed there. There were many construction firms involved in the reconstruction and selection of the section for reconstruction was to be made by each company. Thus, it became necessary to prepare unified guidance for the constructors to set a standard on the selection of the location to be restored and the measures to be taken by them. Figure5 shows the procedure adopted for the selection of countermeasures.

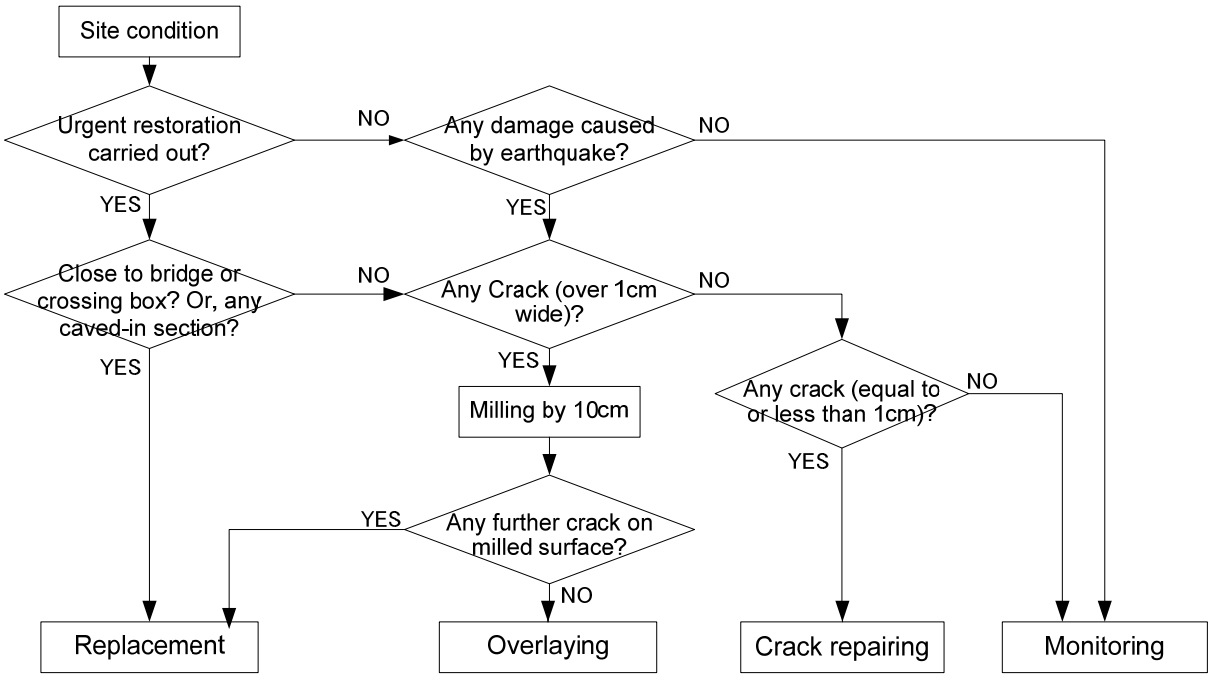

Figure5. Selection flow of restoration method

(7) PUBLIC RELATIONS

In order to obtain the understanding and cooperation by road users and the roadside residents on the disaster relief work, sign boards as shown in Figure6 were installed and fliers were distributed in both of which information of the relevant website was available. At the same time, the sense of integrated construction was shown by unified designs and colors including safety vests. The board in Photo2 indicated the remaining length in terms of time spent and the predicted time of opening to traffic in the restricted section.

Figure6. Information board

Traffic jam information on Route 17

From here to Koide town

It takes about 70 minutes
At 10 o'clock

Nagaoka National Highway Office, The Ministry of Land, Infrastructure, Transport and Tourism

Photo2. Traffic jam information board

5.3 EXAMPLE OF RECONSTRUCTION

A pair of photos below shows a retaining wall rebuilt by the urgent restoring work and the full scale reconstruction work. The collapsed block was removed and the embankment was protected with sand bags in the restoration. The reconstruction made the wall, drainage system and frontage as they had been.

Urgent restoration **Full scale construction**

Photo3. Example of reconstruction

ACKNOWLEDGEMENT

In this disaster relief work, there were various problems which could not be encountered in a normal construction work. The increased volume of construction work was one of them. However, the construction in a limited time was completed without any accident and contributed to the restoration of the area damaged by the earthquake, of which the authors are very proud. Also, the authors would like to highly appreciate the integrated efforts and cooperation by all people concerned.

REFERENCE

1) "The Great Chuetsu Earthquake Disaster, 1st Volume- Before it snows –", Niigata Prefecture, March, 2006